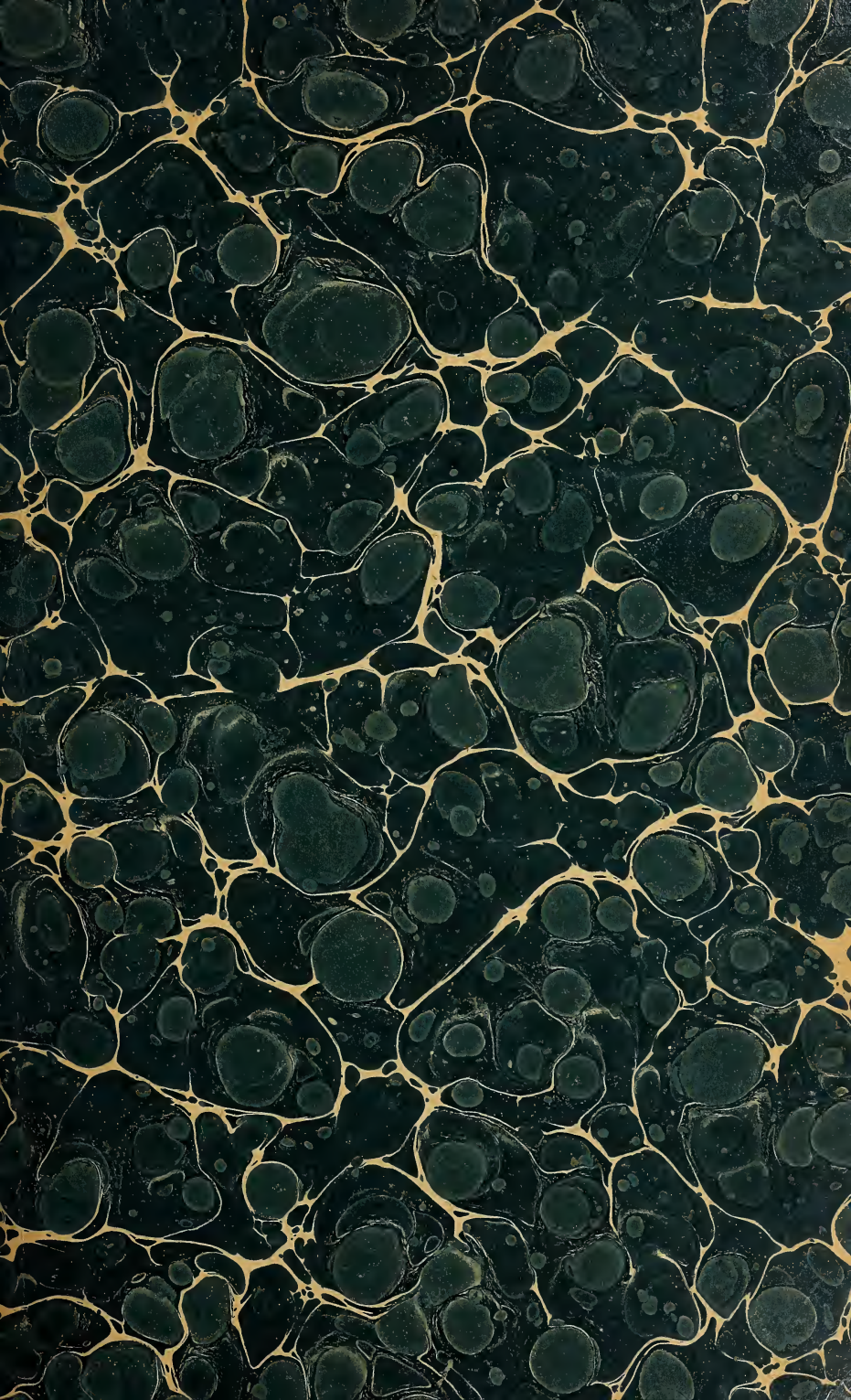

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# United States Department of Agriculture,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist.

## THE GREENHOUSE WHITE FLY.

(*Aleyrodes vaporariorum* Westw.)

By A. W. Morrill,
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The damage by the greenhouse white fly to tomato, cucumber, and many other plants growing under glass easily places it in the front rank of greenhouse pests. In many cases it would be impossible to grow certain crops in forcing houses without the aid of remedial measures. A specific instance is on record where, in a western Massachusetts town, the attacks of this insect resulted in the total loss of a greenhouse crop of tomatoes and cucumbers valued at $4,000.

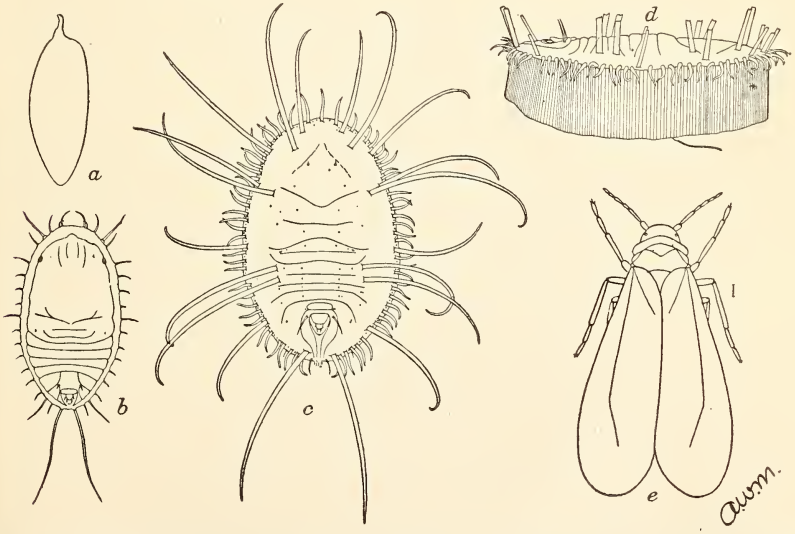


Fig. 1.—*Aleyrodes vaporariorum:* *a*, egg; *b*, young larva; *c*, pupa, top view; *d*, pupa, side view; *e*, adult—*c*, *d*, *e*, about 25 times natural size; *a*, *b*, still more enlarged (*a*–*d*, after Morrill, Tech. Bul. Mass. Exp. Sta.; *e*, original).

During the past few years many appeals for remedies have been made to the editors of our horticultural journals, to many State experiment stations, and to the United States Department of Agriculture; yet, although it is not, in reality, a difficult insect to control, the remedial methods which should be followed are far from being generally known among the many greenhouse men who suffer from its depredations.

## HISTORY, ORIGIN, AND DISTRIBUTION.

The records of the greenhouse white fly date back to 1856,[a] when Prof. W. O. Westwood, of England, recognized it as a previously undescribed species. The first published record, so far as is known to the writer, of the existence of the insect in this country was in the year 1870, when Dr. A. S. Packard, at that time Massachusetts State entomologist, reported it as occurring in abundance on tomato plants at Salem, Mass.[b]

Two places have been suggested as the original home of this species, viz, Mexico and Brazil, but while presumably the origin is tropical American, there is no definite information on this point. Of more importance from a practical standpoint is its present distribution. Besides its occurrence in Europe, Canada, and Mexico, it is known to be widely distributed in greenhouses throughout the eastern United States, and without doubt it occurs more generally than the published records show. We have specific reports of its occurrence in greenhouses in the States of Maine, New Hampshire, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Illinois, Indiana, and Michigan, also in the District of Columbia.

## FOOD PLANTS.

The insect under consideration is notable for its very general feeding habits, having already been recorded as breeding on over 60 different kinds of plants. Of these the following are of the most economic importance: Aster, chrysanthemum, salvia, lantana, fuchsia, coleus, ageratum, primula, geranium, heliotrope, rose, eggplant, bean, melon, lettuce, cucumber, and tomato. The two last named suffer the most serious injury from this insect, perhaps more than the other greenhouse plants together, although not infrequently there are reported serious losses in greenhouses devoted to one or more of the other plants mentioned.

## DESCRIPTION AND LIFE HISTORY.

The mature white flies of both sexes are four-winged insects scarcely more than 1½ mm. or three-fiftieths of an inch in length. The adult

[a] Gardeners' Chronicle, p. 852. [b] Agriculture of Massachusetts for year 1870.

white flies, as well as the scale-like larvæ, are provided with sucking mouth parts. In a short time after the emergence of the adult from the pupa case, the body, legs, and wings become covered with a white, waxy substance which gives this, as well as other species of the genus, a characteristic floury appearance. The adults feed nearly continuously during their existence. If deprived of food, they will rarely live for a longer period than three days under ordinary temperature conditions. The longest recorded length of life of one of these insects in the adult condition is thirty-six days, but it seems probable that the average length of adult life is much greater than this instance would indicate. The largest number of eggs which an adult white fly is positively known to have deposited is 129, but this number is probably below the average. Indeed, the specimen which produced this number of eggs with little doubt deposited over 50 others which were not recorded. The number of eggs deposited per day by an adult female white fly in a laboratory has been found to average very nearly four. Probably in the warmer temperature of a greenhouse this number is greater by one or two eggs per day. These observations, even though falling short of showing the normal increase in numbers of this species, emphasize the importance of a remedy which will, above all, destroy the adults and check at once the rapid deposition of eggs. A pecularity of the egg-laying habits of this and some other species of white fly is the tendency to deposit the eggs in a circle while feeding, using the beak as a pivot. These circles, when completed, are about 1½ mm. in diameter and usually contain from 10 to 20 eggs each. On the more hairy leaves groups of eggs of this kind are less frequently met with than on those which are more nearly smooth. The majority of the adults are found upon the upper and newer leaves of the food plant. They are almost invariably found upon the underside of the leaves, and it is here that nearly all the eggs are deposited, although many are found upon the tender stems and leaf petioles and a very few scattering ones on the upper surfaces of the leaves.

The eggs are distinguishable with difficulty by the naked eye, being but one-fifth of a millimeter, or one one hundred and twenty-fifth of an inch, in length. They are more or less ovoid in form and suspended from the leaf by a short, slender stalk. With ordinary greenhouse temperatures the eggs hatch in from ten to twelve days. The newly hatched insect is flat, oval in outline, and provided with active legs and antennæ. It rarely crawls farther than one-half inch from the empty eggshell before settling down and inserting into the tissue of the leaf its thread-like beak. After feeding for five or six days, the insect is ready to molt its skin. The second and third stages are much alike, except in size, and differ principally from the first stage in that the legs and antennæ are vestigial and apparently functionless. These two stages occupy from four to six days each.

The so-called pupal stage, up to the time when growth ceases, is in reality the fourth larval stage, the fourth larval skin enveloping the true pupa. The pupæ and empty pupa skins are quite conspicuous when the insects are abundant. Their outline is similar to that of the larvæ, but they are thicker and box-like, about three-fourths of a millimeter, or three-hundredths of an inch, in length and provided with long, slender wax rods or secretions which are useful in distinguishing this from nearly allied species of the white fly.

The entire stage from the insect's third molt to the emergence of the adult form lasts from twelve to sixteen days in the laboratory and greenhouse. The adult emerges from a T-like opening, leaving the glistening white pupa case attached to the leaf. At first the wings of the adult are crumpled close to the body, giving them a peculiar appearance. In the course of a few hours the wings unfold and the insect has then completed its development, which has extended over nearly five weeks, if under the ordinary temperature conditions of a greenhouse.

### CLOSELY RELATED FORMS.

In addition to the one here discussed, there are but two other species of white flies which are likely to be met with in the greenhouse. A white fly found infesting citrus plants would be likely to be the orange white fly (*Aleyrodes citri* Riley and Howard), while one infesting strawberry plants, either in the greenhouse or in the field, would probably prove to be the strawberry white fly (*Aleyrodes packardi* Morl.). The latter species resembles the one commonly found in greenhouses, but fortunately its list of food plants is much more restricted, it being apparently unable to subsist on the tomato.

### APPEARANCE OF INFESTED PLANTS.

As already stated, the upper leaves of a plant are preferred by the adult females for the deposition of their eggs. Thus there is a slow but continuous migration of adults upward to keep pace with the unfolding of the leaf buds. On thoroughly infested plants we find on the uppermost leaves only adults and freshly laid eggs; a little lower on the plants we find eggs in the process of hatching; and, finally, on the lowermost parts of the plants we find discolored, shriveled leaves with many pupæ and emerging adults and few, if any, unhatched eggs or young larvæ. The larvæ and pupæ secrete little globules of honeydew, so named after the material of a like nature secreted by plant lice. These globules usually either drop or are forcibly ejected, and, falling on the upper surface of leaves directly below, give them a glazed appearance. This is frequently followed by the growth of a sooty fungus which hastens the complete destruction of the leaf.

When overcrowding of the young occurs, this fungus growth finds favorable conditions for its development on the under surface of the

leaf, resulting in the destruction of many of the immature insects. Owing to the interference with the respiratory processes of the leaf, both by the bodies of the insects themselves and by the fungus growths due to them, badly infested plants have a tendency to wilt when exposed to the sun's rays. In seriously infested greenhouses the leaves of the plants gradually die, the lower leaves first, and if unchecked the insects greatly impair the value and vitality of the plants, even though they do not actually cause their total destruction.

### PREVENTIVES.

The importance of preventive measures in combating the white fly in greenhouses is not due to the inefficiency of properly applied remedies, but to the fact that in many cases the tiny depredator is unobserved until considerable injury has been accomplished. With little trouble and expense one may, in a large measure, preclude the possibility of this and other pests appearing in the winter in greenhouses which are unused during the summer months. The introduction of the insect into noninfested floral establishments may be prevented by avoiding the introduction of infested plants unless first subjecting them to a fumigation in a tight fumigating box, based on the directions hereafter given for entire greenhouses. Vegetable houses, which are not used during the summer months, allow of a practice which not only greatly reduces the chances of the white fly appearing in the house during the growing season, but may result in the house being successfully kept free from thrips and other insect pests during the whole or a considerable part of the season. The practice referred to consists in removing from the house all vegetation, even the smallest weeds, and fumigating the tightly closed greenhouse with hydrocyanic-acid gas at the rate of 5 or more ounces per thousand cubic feet of space for a ten hours' exposure.

### REMEDIES.

*Fumigation with hydrocyanic-acid gas.*—This has been found to be the most successful means of controlling the white fly in greenhouses. Its success in this case is due to the susceptibility of the adults and larvæ of these insects to a comparatively long exposure to a small amount of the gas. Many experiments have been conducted with a view to determining the usefulness of this gas against the greenhouse white fly, the amount of gas to be generated, and the length of exposure necessary to produce the best results.[a] Experiments of this kind thus far have been with tomato and cucumber plants, but as these plants are among those most liable to injury from improper fumigation with hydrocyanic-acid gas, a wide range of usefulness is indicated by the success thus far obtained.

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[a] Conn. Station Bul., No. 140; New Hampshire Station Bul., No. 100; Mass. Station Tech. Bul., No. 1; Maine Station Bul., No. 96; Can. Entomologist, XXXVI, p. 35; American Gardening, XIX, p. 741.

*Amount of potassium cyanide to use and length of exposure.*—Experiments and practice have shown that the white fly is destroyed in all except two stages (egg and late pupal) by an amount of potassium cyanide which is extremely small as compared with the amounts generally recommended for other insect pests. As small an amount as 0.005 gram[a] per cubic foot of space, or between one-fifth and one-sixth ounce per 1,000 cubic feet, for three hours' exposure, has been used with success,[b] while as large an amount as 1 ounce per 1,000 cubic feet for an "all-night exposure," in a house containing infested tomatoes, has been reported to have given, in one instance, a like result.[c] On the other hand, Mr. E. C. Rittue, of the Bureau of Plant Industry of the Department of Agriculture, in attempting to control the white fly infesting tomatoes in a greenhouse on the grounds of the Department, found that 0.01 gram per cubic foot, or one-third ounce per 1,000 cubic feet, slightly injured the plants when the exposure exceeded thirty minutes. This treatment for thirty minutes destroys only the adults. The greenhouse is a new one and, judging from the great difference in the results obtained there and in other houses whose fumigation has been recorded in various publications, it is tighter and does not allow the gas to escape as readily as does the average forcing house.

This shows that the greatest difficulty attending the use of hydrocyanic-acid gas, in greenhouses containing plants as susceptible to injury by it as are the cucumber and tomato, is the difference in the tightness of different greenhouses. It is consequently impossible to give specific directions which will be suitable under all circumstances. A fumigation with hydrocyanic-acid gas which will kill adults only is not effective for practical use in checking the multiplication of the white flies. Rather than this, the method of control described under the heading, "Treatment when the use of hydrocyanic-acid gas is undesirable," is greatly to be preferred.

In most greenhouses, probably 0.007 gram of potassium cyanide for each cubic foot of space for an exposure not exceeding three hours represents the amount which will prove most effective for treatment of the insects without injury to tomato or cucumber plants. In many cases 0.01 gram per cubic foot has been found suitable for the same exposure, but this should not be used except in loose greenhouses where, after trial, a smaller amount is found ineffective. In all greenhouses when an attempt is to be made to control the white fly with hydrocyanic-acid gas, it is advisable to first use not more than 0.005 gram per cubic foot of space for a three hours' exposure. If this amount is sufficient for the house, none of the adults will recover after the fumigation, though in the course of two or three days many more

[a] 28.35 grams=1 ounce. [b] Mass. Station Tech. Bul., No. 1, p. 46.
[c] American Gardening, XIX, p. 741.

will emerge from the pupa cases. The larvæ, when destroyed, as they should be by the fumigation, change in two or three days from their normal glistening, greenish color to a yellowish or brownish color. When this result is not obtained by the first test, one or more further tests should be made, increasing the amount of potassium cyanide 0.001 gram per cubic foot of space for each test, with three days intervening to note results, until an amount is reached which is sufficient to destroy the larvæ, or until the tender leaves of the plant show injuries as a result of the fumigation.

Tests, thus far, with other greenhouse plants likely to be attacked by the white fly, according to available records, have all been for a much shorter exposure than three hours and with a much larger amount of potassium cyanide, but it is probable that in case plants other than the cucumber and tomato require treatment for this insect, preliminary tests in a fumigating box or in a small greenhouse will show that the amount of chemicals and length of exposure recommended for these two can be used without the slightest danger to other plants. In most cases much larger rates of potassium cyanide per cubic foot can be used.

*Time to fumigate, preparation of greenhouse, and method of generating gas.*—Fumigation of plants with hydrocyanic-acid gas should be at night and the foliage of the plants should be dry. The greenhouse to be treated should be made as tight as possible, all entrances but one closed and locked, and arrangements made to open a few ventilators from the outside at the expiration of the period of exposure. A house when fumigated should not be unnaturally tight as a result of rain or snow, otherwise the greater amount of gas confined in it under these conditions may injure the plants. The materials used for the generation of the gas are 98 per cent potassium cyanide, commercial sulphuric acid, and water, the proportions generally used being one-half more acid (liquid measure) than potassium cyanide, and one-half more water than acid. Having determined the cubic contents of the house and the total amount of potassium cyanide, sulphuric acid, and water to be used, these should be divided into parts representing each 25 feet of length of the greenhouse. Owing to the small amounts of the acid and water, small receptacles must be used. Six or 8 inches is a desirable height for the receptacles, while the diameter should be as small as possible to use, preferably not more than $2\frac{1}{2}$ inches. They should be either of earthenware or glass. In many cases, ordinary glass tumblers will be suitable, though the diluted acid should never more than one-fourth fill the receptacle; otherwise the violent chemical action which follows the introduction of the potassium cyanide might result in the loss of considerable of the material. Each lot of the potassium cyanide should be pulverized or broken up into small pieces, wrapped in thin paper, and laid beside one of the receptacles,

these being placed at intervals of about 25 feet on the floor of the house. In each receptacle first pour the proper amount of water and then the acid. Beginning with the end of the house farthest from the exit, drop into each receptacle, in succession, the package of potassium cyanide, proceeding as quickly as possible toward the exit. During the few seconds the operator is in the house after the generation of the gas is started, the breath should be held to prevent even the least bad effects. Close and lock the door of the house and, after three hours, partially ventilate it by opening the ventilators, previously arranged for opening from the outside. One ventilator for every 25 or 30 feet, opened for ten or fifteen minutes, is sufficient to protect the plants from possible bad effects of overexposure to the gas. Before inhaling air in the house, however, the ventilation should be more thorough, so that no odor of the gas, which is much like that of peach pits, can be detected. The morning after the fumigation the contents of the receptacles should be buried.

*Time for subsequent fumigations.*—A single fumigation, according to the directions given above, will destroy practically all of the insects except the eggs and some of those in the late pupal stage. Although one such treatment might check the insects so that they would not cause noticeable damage for weeks, in many cases it would be the part of economy to give two more fumigations at times which a knowledge of the life history of the white fly indicates would be most advantageous. Knowing that the egg and late pupal stage of the insect are not to any great extent affected by the treatment recommended, while all the other stages may be destroyed, and knowing the duration of each stage, we can outline a plan of treatment which will practically eradicate the pest in the worst-infested greenhouses. Two subsequent fumigations two and four weeks, respectively, after the first will subject to the gas all of the white flies in the house in stages wherein, under ordinary circumstances, they are unable to withstand its destructive effects.

*Treatment when the use of hydrocyanic-acid gas is undesirable.*—Fumigation with tobacco fumes, made by burning the refuse stems and leaves, has no effect on the greenhouse white fly beyond temporarily stupefying the adults. The adults may be destroyed, however, by vaporizing in the infested house certain tobacco extracts which are sold in liquid form. To accomplish this result preliminary tests should be made, first using the amount recommended in the directions accompanying the preparation. The attempt to control the greenhouse white fly by means of tobacco extracts alone has never, to the writer's knowledge, proven successful, while many cases of failure have been reported. The frequent fumigation necessary to control the insect when once it has become abundant would be impractical and costly. However, in connection with syringing the plants with a

soap solution such a treatment may sometimes be of value, although only when the use of hydrocyanic-acid gas is impossible or for some reason undesirable.

Among the sprays, the best brands of whale-oil soap, used in the proportion of 1 to 1½ ounces per gallon of water, have been found to destroy all of the white flies except the eggs, a small percentage of the nearly mature pupæ, and from 25 to 50 per cent of the adults which escape the spray by flying from the plants. It is not advisable to syringe tomato plants in greenhouses at any time, when avoidable, as syringing interferes with pollination and produces a damp atmosphere which promotes rot, but the injury by syringing may be as nothing compared with that which is caused daily by the insects. When the use of hydrocyanic-acid gas is impractical, an all-night fumigation with a tobacco extract is recommended, followed during the next day by a syringing with a solution of whale-oil soap or its equivalent.

*Comparative cost of the treatment.*—Potassium cyanide costs from about 30 to 50 cents per pound, according to the amount purchased. Commercial sulphuric acid costs from about 2½ to 10 cents per pound. The entire cost for a single fumigation of a greenhouse containing 20,000 cubic feet is between 20 and 30 cents. The labor required is scarcely, if any, greater than for fumigation with other materials. A single fumigation with a suitable tobacco extract would cost, in a house of the same size, at least $1.50, and the cost of labor for the syringing which is recommended to follow such fumigation would probably not be less than $1. The soap required would cost only a few cents, though possibly as much as the materials used in a fumigation with hydrocyanic-acid gas.

## CAUTIONS.

Hydrocyanic-acid gas is one of the deadliest poisons known, and should always be handled with the greatest care. Never hold the potassium cyanide in the bare hand when pulverizing, but wrap up the lumps in two or more thicknesses of cloth before breaking with a hammer. Dust or small pieces of potassium cyanide should not be thrown away in exposed places, but always buried, as should the contents of the receptacles of the chemicals after the fumigation. Never inhale air in a greenhouse after the generation of gas has begun, and provide against anyone entering the house before it is properly ventilated.

Approved:

JAMES WILSON,
*Secretary of Agriculture.*

WASHINGTON, D. C., *February 15, 1905.*

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